PB85-212124

Impact of Drilling Fluids on Seagrasses An Experimental Community Approach

University of West Florida, Pensacola

Prepared for

Environmental Research Lab., Gulf Breeze, FL

Jun 85

U.S. Department of Commerce
National Technical Information Service
NTIS

PB85-212124

EPA/600/D-85/121
June 1985

IMPACT OF DRILLING FLUIDS ON SEAGRASSES:
An Experimental Community Approach

by

R. Dana Morton*, Thomas W. Duke**, John M. Macauley**,
James R. Clark**, W. Allen Price*, Stacia J. Hendricks**,
Stacy L. Owsley-Montgomery*, and Gayle R. Plaia****

*University of Florida, Department of Biology,
Pensacola, FL 32514-0101.
**Environmental Research Laboratory, U.S. Environmental
Protection Agency, Gulf Breeze, FL 32561.
***Grayfield Inn--Cumberland Island, Fernandina Beach,
FL 32034.
****785 56th Ave. S., St. Petersburg, FL 33705

ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
GULF BREEZE, FL 32561

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/600/D-85/121	2.	3. RECIPIENT'S ACCESSION NO. PB85 212124/AS
4. TITLE AND SUBTITLE IMPACT OF DRILLING FLUIDS ON SEAGRASSES: AN EXPERIMENTAL COMMUNITY APPROACH		5. REPORT DATE June 1985 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) R.D. Morton, T.W. Duke, J.M. Macauley, J.R. Clark, W. Allen Price, S.J. Hendricks, S.L. Owsley-Montgomery & G.R. Plaia		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of West Florida Department of Biology Pensacola, Florida		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Research Laboratory - Gulf Breeze, FL Office of Research and Development U.S. Environmental Protection Agency Gulf Breeze, FL 32561		13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE EPA/600/4
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

Effects of a used drilling fluid on an experimental seagrass community (Thalassia testudinum Konig et Sims) were measured by exposing the community to the suspended particulate phase (SPP) in laboratory microcosms. Structure of the macroinvertebrate assemblage, growth and chlorophyll content of grass and associated epiphytes, and rates of decomposition as indicated by weight loss of grass leaves in treated and untreated microcosms were compared. There were statistically significant differences in community structure and function among untreated microcosms and those receiving the clay and drilling fluid. For example, drilling fluid and clay caused a significant loss in the number of the ten most numerically abundant (dominant) macroinvertebrates, and drilling fluid decreased the rate at which Thalassia leaves decomposed.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS (This Report) UNCLASSIFIED	21. NO. OF PAGES 27
	20. SECURITY CLASS (This page) UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ACKNOWLEDGMENT

We thank D. Hansen for suggesting research with seagrass communities, J. Kelly, M. Harwell, G. Thayer and R. Iverson for advice on experimental protocol, C. Deans for suggestions for experimental design and statistical analysis, R. Livingston and associates for comparative identification of macroinvertebrates and several colleagues from this laboratory for reviewing the manuscript. This research was sponsored in part through Cooperative Agreement CR-811649 between the U.S. Environmental Protection Agency and the Univeristy of West Florida, C. D'Asaro, Principal Investigator.

ABSTRACT: Effects of a used drilling fluid on an experimental seagrass community (Thalassia testudinum König et Sims) were measured by exposing the community to the suspended particulate phase (SPP) in laboratory microcosms. Structure of the macroinvertebrate assemblage, growth and chlorophyll content of grass and associated epiphytes, and rates of decomposition as indicated by weight loss of grass leaves in treated and untreated microcosms were compared. Health of the plants and structure of the macroinvertebrate assemblage maintained in the laboratory were compared periodically with the seagrass community from which the plants and attendant sediment were taken.

Treated microcosms were exposed to either 190 parts per million (ppm), volume to volume, of suspended particulate phase (SPP) or an equivalent amount of montmorillonite clay. Untreated microcosms received only flowing water from Santa Rosa Sound. Sixteen replicates were provided for each treated and untreated set.

There were statistically significant differences in community structure and function among untreated microcosms and those receiving the clay and drilling fluid. For example, drilling fluid and clay caused a significant loss in the number of the ten most numerically abundant (dominant) macroinvertebrates, and drilling fluid decreased the rate at which Thalassia leaves decomposed.

KEY WORDS: community tests, toxicity, drilling fluids, experimental microcosms, aquatic toxicology, community structure and function

Seagrass communities occupy a unique niche in shallow coastal waters that interface between man's activities in terrestrial and marine ecosystems. The communities influence coastal systems through high productivity (300-600 g dry weight/m^2/year), as substrate for a large biomass of epiphytes, in cycling of phosphorus, sulfur, and nitrogen, by stabilization of sediment, and by contributions to major food webs (1-3). Man's activities near and within coastal ecosystems can affect seagrass adversely, and thus the communities of which they are an integral part.

These productive communities are sensitive to pollutants such as dredged material (4,5), turbidity from suspended particulates (6), and oil spills (7). Venezuelan crude oil spilled from a tanker killed large numbers of invertebrates, prawns, and entrapped oil-killed vegetation in a Thalassia bed, and extensive areas of bottom eroded when the Thalassia died (8). Other studies (9, 10) indicated that associated fauna are more likely to suffer adverse effects from oil pollution than vegetative parts of seagrass communities.

A related issue is the potential impact on seagrasses by drilling fluids (muds) discharged from oil and gas platforms during rotary-bit drilling operations in near-shore waters. Seagrass communities could be adversely affected by chemicals in the fluids and by contact with the drilling fluids and cuttings. Functions of the drilling fluids include transportation of cuttings produced as the drill passes through various substrates, lubrication of the bit, and formation of an impermeable layer on the inside of the bore hole to maintain formation pressure. Water-based drilling fluids are used in U.S. marine drilling operations and usually consist of bentonite and other clays, barium sulfate (barite) as a weighting agent, lignosulfates as thinners, and various "speciality" items to

control pH or bacteria. Diesel and other oils have been added to some drilling fluids to enhance lubrication (11).

In practice, drilling fluids are cycled through the various systems of the drilling platform until they no longer serve the desired needs, and are discharged into surrounding waters. The amount of fluids discharged depends upon many factors including the type of well, that is, exploratory or production. Approximately 3,000 to 6,000 bbl (42 gal/bbl) of wet solids are discharged from the solids control system during the life of a well (11). Based upon a weight of 25 lbs of solids per gal, this amounts to 1,575 to 3,150 tons of these materials released per single well.

There is concern that drilling fluids discharged into waters near seagrass beds could be transported to and adversely affect the beds (Personal Communication, Maurice Rinkel[1]). Potentially, the seagrass beds could be adversely affected physically by fluid covering the bed or adhering to plants, through reduced photosynthetic activity because of increased turbidity, and by alteration of the size of sediment particles. From an ecosystem perspective, the drilling fluids, if toxic, could alter structure and functions vital to maintenance of the seagrass community.

This paper presents a relatively rapid (42-day) ecotoxicity test that demonstrates effects of drilling fluids on structure and function of a seagrass community maintained in the labortory. Results of a test conducted to evaluate the impact of a used drilling fluid from an operating rig in the Gulf of Mexico are presented as an example of the test's utility and sensitivity.

METHODS

A seagrass community microcosm system was developed to test effects of used drilling fluid in the laboratory. Microcosms have been used

successfully by others to evaluate the effects of pesticides and toxic organics on various communities or parts of communities (12, 13) and to determine the effects of a drilling fluid on a benthic community (14).

Portions of a seagrass community were brought into the laboratory, exposed to drilling fluid and clay, harvested, and the data subjected to various analyses. Certain aspects of the health and structure of the seagrass community in the microcosm were compared periodically with characteristics of the seagrass community from which they were collected. We evaluated effects of the drilling fluid and clay on structure of macrobenthos, growth and production of the grass and epiphytes, and the decomposition of grass leaves. The flow diagram (Figure 1) indicates the sequence of collecting, testing, and analyzing samples.

Sample Collection

Samples of a Thalassia testudinum König et Sims community from Santa Rosa Sound, near our laboratory, were collected by divers with a 14.0-cm (inside diameter) coring device constructed of acrylic tubing. The grasses were cored to a depth of approximately 10.0 cm, placed intact inside a clear Plexiglas® cylinder (15.9-cm inside diameter, 50.0-cm height), and transported to the laboratory within two hours after collection. Thus, each cylinder was a microcosm containing Thalassia plants, epiphytes, and natural sediment substrate with associated organisms. Rarefaction analyses (15) indicated that 16 cylinders contained more than 90 percent of the macroinvertebrate species present in an equal area in the Thalassia bed. Therefore, 16 microcosms were utilized for each test treatment.

Test Procedure

The microcosms were maintained in flowing seawater and exposed to either drilling fluid or montomorillonite clay; control microcosms were

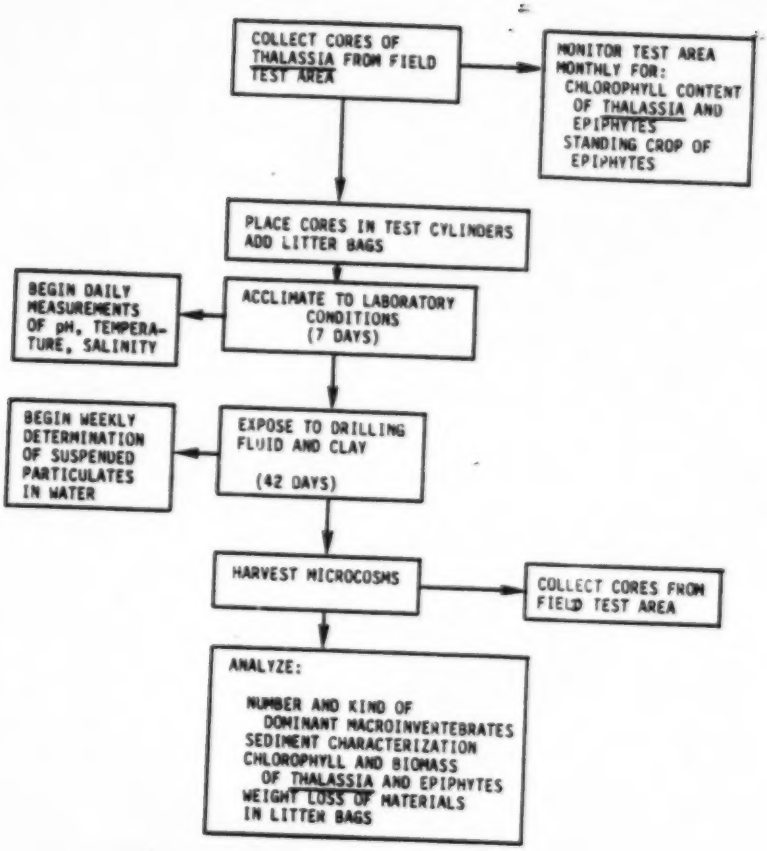
COLLECT CORES OF THALASSIA FROM FIELD TEST AREA
MONITOR TEST AREA MONTHLY FOR:
CHLOROPHYLL CONTENT OF THALASSIA AND EPIPHYTES
STANDING CROP OF EPIPHYTES
PLACE CORES IN TEST CYLINDERS ADD LITTER BAGS
BEGIN DAILY MEASUREMENTS OF pH, TEMPERATURE, SALINITY
ACCLIMATE TO LABORATORY CONDITIONS (7 DAYS)
BEGIN WEEKLY DETERMINATION OF SUSPENDED PARTICULATES IN WATER
EXPOSE TO DRILLING FLUID AND CLAY (42 DAYS)
HARVEST MICROCOSMS
COLLECT CORES FROM FIELD TEST AREA
ANALYZE:
NUMBER AND KIND OF DOMINANT MACROINVERTEBRATES
SEDIMENT CHARACTERIZATION
CHLOROPHYLL AND BIOMASS OF THALASSIA AND EPIPHYTES
WEIGHT LOSS OF MATERIALS IN LITTER BAGS

Fig. 1 - Flow diagram showing the sequence of collecting, testing, and analyzing samples.

maintained in flowing seawater (Morton - Masters Thesis Proposal[2]). The clay exposure served as a sediment "control" so that any effects of the drilling fluid, a mixture of chemicals and solids, could be identified as chemical or physical effects. Three sets of 16 microcosms (total 48) were arranged randomly in the laboratory to receive flowing seawater and appropriate treatments. Unfiltered seawater was pumped from Santa Rosa Sound to the settling reservoir above the test apparatus (Fig. 2). A 1-mm Nitex® filter was fitted over the delivery standpipe in the settling reservoir to exclude larger material from reaching and clogging the delivery tubes to the microcosms. Seawater flowed from the settling reservoir to a baffled 20-litre Plexiglas® primary head-box suspended over the microcosms. Twelve glass standpipes, six at each end of the head-box, were fitted with silicone stoppers and calibrated to deliver 660 ml/min. A larger diameter glass overflow standpipe at each end of the primary head-box maintained the water at a constant level. From the twelve standpipes, the water entered glass mixing tubes that delivered the seawater to twelve secondary head-boxes. From each secondary head-box, seawater was delivered separately to four microcosms at a rate of 115 ml/min (±10 ml/min). This theoretically provided one turnover in each microcosm every 60 min. Also, airstones were placed in the microcosms to help prevent anaerobic conditions from developing at the sediment-water interface and to keep the drilling fluid and clay in suspension. Experiments with fluorescent dye indicated a well-mixed water column in the microcosms.

Lighting for the experiment was provided by eight high-intensity fluorescent bulbs (G.E. Power Groove®) rated at 250 watts. Suspended 46.0 cm above the microcosms, the bulbs provided an average light energy

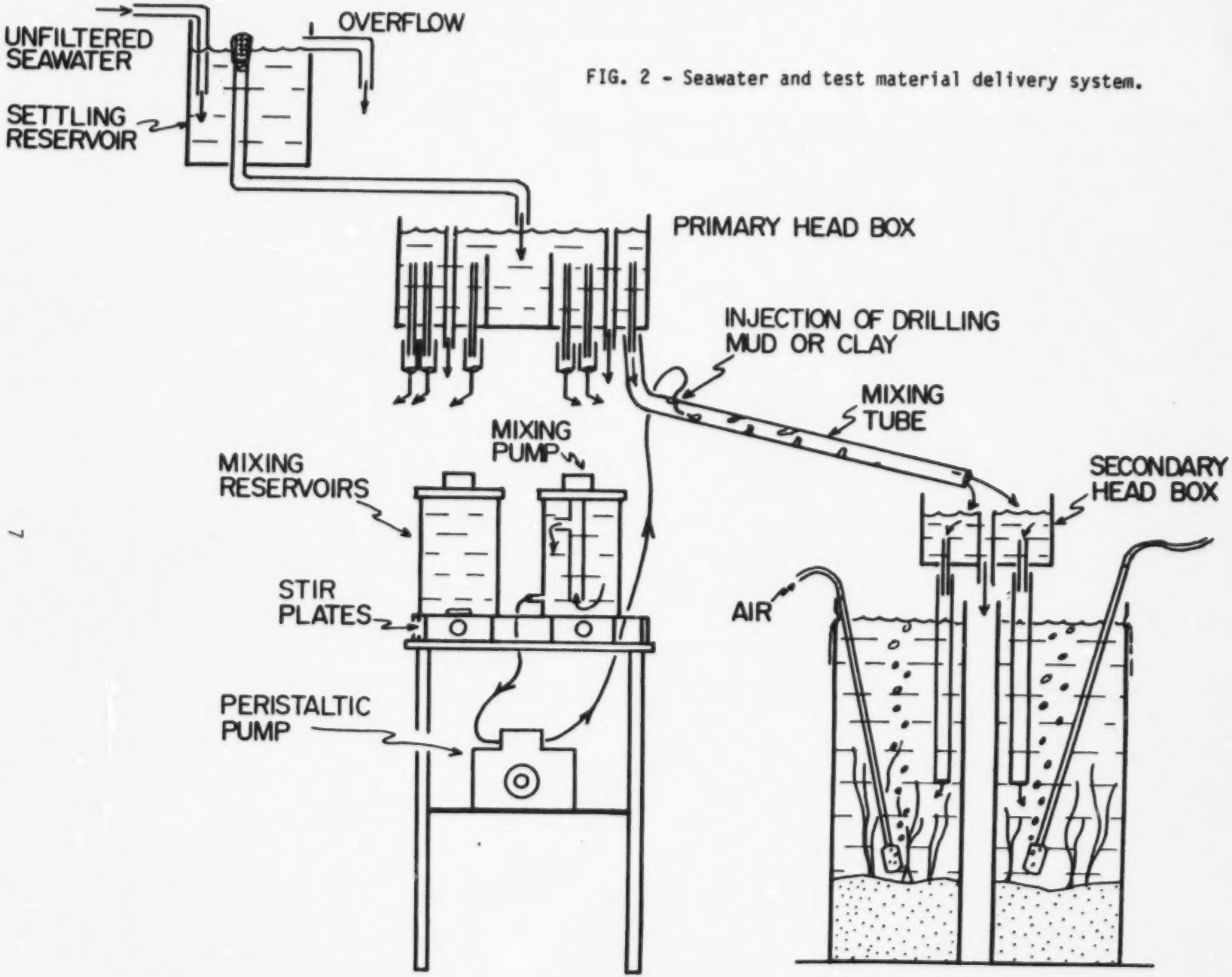

FIG. 2 - Seawater and test material delivery system.

of 26 $\mu E/m^2/s$ on the surface of the water column within the microcosms. The photoperiod during the test was approximately 12h light and 12h dark.

Preparation and Delivery of Drilling Fluid and Clay

The drilling fluid used in this study was collected from an operating oil rig in the Gulf of Mexico and supplied to our laboratory by the Petroleum Equipment Suppliers Association (PESA). The chemical characteristics of this drilling fluid, designated P-2, and the log from the well where it was collected can be found in Duke and Parrish (16). The P-2 fluid contained approximately the same concentration of metals as did ten other used drilling fluids from the PESA project, but contained more diesel oil than nine other fluids. The suspended particulate phase (SPP) of the drilling fluid was used in this experiment and was prepared according to Petrazzuolo (17) except that a 4:1 ratio of seawater to drilling fluid was used to prepare the SPP phase. The total nonfilterable residue for the SPP was calculated according to procedures of the APHA (18) except that a 0.4 µm polycarbonate filter was used. Milgel®, a common drilling fluid additive consisting of sodium montmorillonite clay, was prepared to equal the density of drilling fluids and delivered to appropriate microcosms as a sediment control. An average of 190 ppm (microlitre/litre) of drilling fluid or clay was delivered to appropriate microcosms. This resulted in 15 mg of solids per litre of water.

Because of the tendency of solids in the test material to settle, two 5 gal mixing reservoirs were equipped with small pumps to keep the two test mixtures, clay and drilling fluid, in suspension. In addition, magnetic stirbars in the reservoirs assisted in keeping material in suspension.

Leaf Litter Bags

Leaf litter or detritus bags were prepared and one bag added to each of the 48 microcosms. The bags were constructed of 2 mm mesh Nytex nylon netting and were 10 cm square. The weight of each bag was determined, dried Thalassia leaves added, and the bags weighed again to determine dry weight of the leaves. Glass rods anchored the bags in the microcosms just above the sediment-water interface.

Harvest and Treatment of Samples

The 48-microcosm test system was harvested randomly at the end of the 42-day test. Fifteen Thalassia leaves with associated epiphytes were taken from each treatment for analysis of biomass and chlorophyll content. One 3.4 cm diameter core was taken from four microcosms per treatment for sediment analysis. Remaining contents were sieved to separate plant and sediment portions and placed into 0.5-mm mesh nylon bags. All portions were immersed in propylene phenoxetol (PPO) in seawater to relax organisms. Plant portions were then fixed in five percent formalin until the animals were picked from them and grass weights (dry) were measured. Sediment portions were placed in ten percent formalin in seawater with 100 mg/litre rose bengal stain. After rinsing in freshwater, the sediments were seived through 1.0-and 0.5-mm sieves. The sieved material was stored in 60 percent 2-propanol until the macroinvertebrates could be sorted and identified. The ten species with the greatest number of individuals were designated "dominant" species. Four litter bags were collected each week for five weeks from each treatment. The bags were removed from the microcosms, rinsed in freshwater, dried at 100°C for 24 h, weighed, and the weight change (loss) calculated. At the conclusion of the test, ten cores were taken from the Thalassia field site and processed in the

same manner as the microcosms.

Measurements of the Thalassia leaf samples included chlorophyll a per g tissue or per cm^2 blade area. Effects on epiphytic communities were observed by measuring differences in epiphytic biomass (ash free dry weight-AFDW) per cm^2 of Thalassia leaf as a biomass indicator, chlorophyll a per g AFDW epiphyte tissue as a community health indicator, and chlorophyll a per cm^2 leaf area as an indicator of photosynthetic potential. Details of these analyses to determine the health and productivity of the epiphytes can be found in Price, et al. (19).

Statistical Analysis

Faunal data were analyzed by a Duncan's post hoc analysis on transformed data LOG (X+1), alpha = 0.05 (20); plant and epiphyte data were analyzed without transformation. Weight loss in litter bags was analyzed as differences between log transformation of initial and final (after five weeks exposure) weights.

RESULTS AND DISCUSSION

Effects on Seagrass Community Structure

Exposure to drilling fluid or clay for 42 days significantly affected the structure of the invertebrate community in microcosms. The effect was reflected in significant differences in numbers of the ten most numerically abundant (dominant) individuals in control and treatment microcosms (TABLE 1). We chose to evaluate the effects on dominants in order to accelerate the identification of species and analysis of data to meet the requirements for a relatively rapid toxicity test. Certainly, inclusion of all species could yield valuable information and additional insight into changes in the community as a result of the treatments.

The impact of the drilling fluid and clay on the macroinvertebrate

TABLE 1 -- Mean number of macroinvertebrates per microcosm for ten numerically abundant species after exposure to drilling fluid and clay.*

Organisms	Treatment		
	Control	Clay	Drilling Fluid
Annelida			
Aricidae philbinae	17 A	17 A	15 A
Armandia maculata	2.4 A	3.3 A	1.1 B
Fabricola spp.	14 A	4.2 B	2.3 B
Mediomastus californiensis	3.7 A	2.8 A	2.9 A
Nereis pelagica	4.6 A	7.0 A	4.9 A
Pista spp.	9.1 A	3.1 B	3.1 B
Prionospio heterobranchia	20 A	16 A	16 A
Tharyx marioni	4.6 A	1.8 A	1.9 A
Total	9.4 A	6.9 B	5.9 B
Arthropoda			
Elasmopus levis	47 A	11 B	4.6 B
Mollusca			
Bittium varium	1.0 A	5.0 A	3.0 A
OVERALL TOTAL	12 A	7.1 B	5.5 B

* Significant differences detected by Duncan's post hoc analysis on transformed data Log (x+1). Letters A, B, and C represent statistically different means, (alpha = 0.05, n = 16).

dominants was reflected in several ways. There were significantly fewer individuals of four dominant species in microcosms exposed to drilling fluid or to clay than in controls (TABLE 1). Three species were significantly reduced in numbers by both drilling fluid and clay. One species, the polychaete Armandia maculata, was significantly affected by drilling fluid alone, indicating a possible toxic effect. Perhaps the most striking effect we observed was the overall reduction of the number of dominant individuals per microcosm in both drilling fluid and clay treatments. Treated microcosms contained approximately one-half the number of individuals as control microcosms.

Effect on Seagrass Community Functions

The drilling fluid and clay adversely altered some aspects of production and health in Thalassia and epiphytes. Plants from the 42-day exposure system with drilling fluid and clay showed significant reduction in chlorphyll a/dry weight leaf tissue. There were also significant reductions in epiphyte biomass (AFDW/cm^2) and epiphytic photosynthetic potential (chlorophyll a/cm^2) in drilling fluid treatments (TABLE 2). We have no explanation for the enhancement of the latter two factors by the clay treatment. Ephiphytes in the drilling fluid and clay treatments at the end of the exposure contained similar amounts of chlorophyll a/g AFDW as did the control. Effects of the drilling fluid treatment on Thalassia production and epiphyte community are discussed elsewhere (19).

The drilling fluid treatment caused a significant decrease in the rate of decomposition of seagrasses, as estimated by weight loss of the litter bags (TABLE 3). We interpret the significant difference between weight loss of leaves in litter bags exposed to drilling fluid and weight loss of those exposed to clay and seawater (the drilling fluid-exposed bags

TABLE 2 -- Effects of drilling fluid and clay on *Thalassia testudinum* and associated epiphytes.*

Parameter	Treatment		
	Control	Clay	Drilling Fluid
Epiphyte			
chlorophyll *a*/g AFDW[1]	11.57 A	10.67 A	11.13 A
chlorophyll *a*/cm^2	1.02 B	1.44 A	0.45 C
AFDW/cm^2	1.00 B	1.40 A	0.50 C
Thalassia			
chlorophyll *a*/g dry wt.	7.3 A	6.2 B	5.3 C

*Significant differences detected by Duncan's post hoc analysis. Letters A, B, and C represent statistically different means, (alpha = 0.05, n = 15).

[1]AFDW = Ash-Free Dry Weight

TABLE 3 Weight loss of *Thalassia* leaves in litter bags.

Treatment	Differences in weight from initial to final (after five weeks exposure) sampling[1] g
Control	3.629 A
Clay	3.077 A
Drilling Fluid	1.347 B[2]

[1]Significant differences detected by Duncan's post hoc analysis on log transformed data. Letters A and B represent statistically different means, ($\alpha = 0.05$, $n = 4$).

[2]One of the microcosms developed a bacteria-like infection that covered the plants and clogged the litter bags. Data from the infected microcosm was not included in the analyses.

lost less weight) as an indication of the effect of drilling fluid on rate of decomposition. Since the clay treatment did not affect decomposition of Thalassia leaves, we believe that the effect was not simply a physical one. Also, the weight of the litter bags in the clay treatment did not differ significantly from the control, indicating that the effect of the drilling fluid treament was not a result of experimental anomalies such as increase in weight of the litter bags due to the accumulation of settling particles.

Comparison of Laboratory and Field Communities

It is reasonable to assume that seagrass communities removed from the field and maintained in the laboratory for six weeks will vary in structure and functions from undisturbed field communities. In order to predict impacts of a stress on field communities based upon data obtained with laboratory communities, it is useful to quantify variances between the communities in as many characteristics as possible. Therefore, at the end of the six-week laboratory exposure, ten cores (equivalent in area to ten microcosms) were removed from the field. Community characteristics such as density of the ten numerically dominant species were quantified, concentrations of chlorophyll a/ of Thalassia leaves and of epiphytes and AFDW of the epiphytes provided valuable comparative data.

A comparison of each of these characteristics between the field cores and control microcosms (on a per-microcosm or per field-core basis) at the time of harvest showed that, among the ten most abundant genera for laboratory control microcosms and field cores, six were common - four annelids, one arthropod, and one mollusc. Seven of the top ten laboratory control genera were found among the total genera identified from the field cores and all the top ten dominants in the field were present in all the

TABLE 4 -- Comparison of laboratory (control and field seagrass communities. The laboratory communities were maintained in flowing seawater for 42 days.

Ten Numbercially Dominant Macroinvertebrates					
Laboratory Microcosms (Control)			Field Cores		
	Organism	Organisms per microcosm		Organism	Organisms per microcosm
* 1.	Elasmopus levi	47	1.	Bittium varium	128
* 2.	Prionospio heterobranchia	20	* 2.	Crepidula maculosa	30
* 3.	Aricidea philbinae	17	* 3.	Aricidea philbinae	9
4.	Fabriciola	14	4.	Mitrella lunata	9
* 5.	Pista sp.	9	* 5.	Prionospio heterobranchia	7
6.	Cymadusa compta	5	* 6.	Nereis pelagica	5
7.	Tharyx marioni	5	* 7.	Pista sp.	5
* 8.	Nereis pelagica	5	8.	Hippolyte pleuracantha	4
9.	Mediomastus californiensis	4	* 9.	Elasmopus levi	4
*10.	Crepidula maculosa	3	10.	Marginella apicina	3

* Common species in Field Core and Control Top 10.

	Thalassia testudinum Plants and Epiphytes	
	Laboratory Microcosm (Control)	Field Cores
Thalassia		
Chlorophyll a/g	7.3 A[1]	4.7 B
Epiphytes		
AFDW[2]/cm[2]	1.0 A	0.697 A
Chlorophyll a/g	11.56 A	8.14 A
Chlorophyll a/cm[2]	1.02 A	0.268 B'

[1] Letters A and B represent significantly different means by Duncan's post hoc analysis ($\alpha = 0.05$, $n = 15$) Treatment means not included

[2] AFDW = ASH FREE DRY WEIGHT

genera identified in laboratory control microcosms (TABLE 4). The only significant difference between laboratory and field in the other measured characteristics was chlorophyll *a*, which was higher in concentration in the laboratory maintained epiphytes (per cm^2 of *Thalassia* leaves) than in those from the field and Chlorophyll *a* in the *Thalassia* leaves also was higher in plants from laboratory microcosms. This elevation of chlorophyll *a* in laboratory organisms could be a natural reaction to less light in the laboratory since laboratory microcosms received from 50 to 80 percent less light than did the field communities on a clear day.

Thus, the laboratory microcosms were reasonably similar to field conditions for the purposes of our tests. It appears more valid to compare the more general aspects of structure and function when extrapolating data obtained on these communities. For example, the effect of the drilling fluid on total numbers of individuals should be considered rather than effect on any one particular genus or species. Our laboratory to field comparisons are consistent with those published by others (22) who conducted a more comprehensive and detailed comparison of benthic communities maintained in the laboratory with those occurring in the field.

Ecological Relevance

We recognize that this test does not yield detailed ecological information. For example, by decreasing the sieve size used in the macroinvertebrate experiments, more information could be obtained on the infractructure of the community. The test did not reveal such functions as predator-prey relationships that are an important factor in these communities. Nevertheless, we believe that the test can detect the more overt impacts and, along with other toxicity tests, can provide useful data for risk assessment.

Risk assessment involves consideration of environmental concentrations of a pollutant as well as effects at those concentrations. The concentration of drilling fluid used was calculated partly from information presented at the Adaptive Environmental Assessment workshop (21) and on ecotoxicological testing experience of the authors. The 190 microlitre/litre (15 mg/litre) concentration of SPP would probably occur only near the point of discharge from a single offshore rig and would occur every other week rather than continuously for six weeks. Conversely, if discharge were from a multi-well platform in shallow water, exposure could be longer than six weeks and could include larger and possibly more toxic particles than normally found in the SPP phase. At the time this experiment was begun, models for predicting the environmental concentrations of drilling fluids were constructed for discharges into waters deeper than 20 m. Although other models have been developed recently, we know of none that have been validated in shallow (<20 m) waters. Exposure of the laboratory community was probably greater in time and amount than a field community would receive if an equal amount of clay and drilling fluid had been applied under field conditions. In the laboratory, drilling fluid and clay formed a one to two-cm deep layer on the bottom of the microcosms. In the field, currents could reduce such accumulation even though the grasses tend to reduce current velocities near the sediment-water interface.

CONCLUSIONS

The test method fulfills the requirements for a relatively rapid ecotoxicity test to assess the potential impact of drilling fluids on seagrass communities, and is discriminating enough to reveal effects on structure and some functions of the system. Sensitivity of the community compared well with sensitivity of single species tested with the same drilling fluid for shorter periods of time (16). In other toxicity tests with marine organisms and drilling fluids, there was a direct correlation between toxicity and concentration of diesel oil (16). Thus, diesel in the drilling fluid probably contributed to effects on the structure and function of our microcosms. This was evident in the degradation rate of seagrass where a significant effect was measured with drilling fluid but not in the clay treatment. The role of diesel was less clear in the reduction of numbers of macroinvertebrates where both drilling fluid and clay treatments had similar effects.

This ecotoxicity test is designed for regulatory purposes when it is often necessary to make environmental decisions in a relatively short period of time without extensive background or monitoring information or time to conduct detailed tests. Our tests with a used drilling fluid from the Gulf of Mexico showed that it significantly reduced the number of dominant macroinvertebrates and reduced the rate of weight loss (decomposition) of Thalassia leaves. In our opinion, if a natural seagrass community were exposed to an equivalent concentration of a drilling fluid with chemical and physical properties similar to those of the fluid we tested, the natural communities would be adversely affectly in the same manner as were the experimental communities. It should be noted that our study was not designed to determine a "no-effect" concentration and it is

conceivable that effects are possible with lower concentrations of the drilling fluid and clay treatments.

Footnotes

[1]Personal Communication. Mr. Maurice O. Rinkel, Florida Institute of Oceanography, 830 First Street South, St. Petersburg, FL 33701.

[2]Morton, R.D. Masters Thesis Proposal. Department of Biology, University of West Florida, Pensacola, FL 32514-0102.

References

[1] Thayer, G.W., Wolfe, D.A., and Williams, R.B., American Scientist, Vol. 63, 1975, pp. 288-296.

[2] Orth, R.J., Heck, K.L. Jr., and Van Montfrans, J., Estuaries, Vol. 7, No. 4A, 1984, pp. 339-350.

[3] Livingston, R.J. Estuaries, Vol. 7, No. 4A, 1984, pp. 377-390.

[4] Odum, H.T., Publication of the Institute of Marine Science, Texas University. Vol. 9, 1963, pp. 48-58.

[5] Briggs, P.T., and J.S. O'Connor. New York Fish and Game Journal. Vol. 18, No. 1, 1971, pp. 17-41.

[6] Zimmerman, M.S. and Livingston, R.J. Marine Biology., Vol. 34, 1976, pp. 297-312.

[7] Zieman, J.C., Orth, R., Phillips, R.C., Thayer, G.W. and Thorhaug, A. in Restoration of Habitats Impacted by Oil Spills, Cairns, J. Jr. and Buikema, A.L., editors. Chapter 2. Butterworth Publishers, Boston, Mass. 1984, pp. 37-64.

[8] Nadeau, R.J. and Berquist, E.T. "Effects of the March 18, 1973 Oil Spill Near Cabo Rojo, Puerto Rico on Tropical Marine Communities," in Proceedings of the 1977 Oil Spill Conference American Petroleum Institute, Washington, D.C., 1977, pp. 535-538.

[9] den Hartog, C. and Jacobs, R.P.W.M. "Effects of the Amoco Cadiz Oil Spill on an Eelgrass Community at Roscoff (France) with Special Reference to the Mobile Benthic Fauna, " Helgol. Meeresunters, 1980, Vol. 33, pp. 182-191.

[10] Chan, E.I. "Oil Pollution and Tropical Littoral Communities: Biological Effects of the Florida Keys Oil Spill, "In Proceedings of

the 1977 Oil Spill Conference (Washington, D.C.: American Petroleum Institute), 1977, pp. 539-542.

[11] National Research Council (U.S.) "Drilling Discharges in the Marine Environment." Panel on Assessment of Fates and Effects of Drilling Fluids and Cuttings in the Marine Environment. National Academy Press, Washington, D.C., 1983, pp. 13-21.

[12] Hansen, D.J. and Tagatz, M.E. "A Laboratory Test for Assessing Impacts of Substances on Developing Communities of Benthic Estuarine Organisms," Aquatic Toxicology, ASTM STP 707, J.G. Eaton, P.R. Parrish and A.C. Hendricks, Eds., American Society For Testing and Materials, 1980, pp. 40-57.

[13] Walsh, G.E., Hansen, D.L., and Lawrence, D.A. Marine Environmental Research. Vol. 7, 1981, pp. 1-11.

[14] Tagatz, M.E., Ivey, J.M., Lehman, H.K., and Oglesby, J.L. Northeast Gulf Science, Vol. 2, No. 1, 1978, pp. 35-42.

[15] Simberloff, Daniel. "Use of Rarefaction and Related Methods in Ecology" Biological Data In Water Pollution Assessment: Quantitative And Statistical Analyses. ASTM STP 652. K.L. Dickson, John Cairns, Jr. and R.J. Livingston, Eds., ASTM, 1978, pp. 150-165.

[16] Duke, T.W. and Parrish, P.R. Results of the Drilling Fluids Research Program Sponsored by the Gulf Breeze Environmental Research Laboratory, 1976-1984, and Their Application to Hazard Assessment. EPA-600/4-84-055. 1984 pp. 27-31.

[17] Petrazzuolo, G. "Proposed Methodology: Drilling Fluids Toxicity Tests for Offshore Subcategory; Oil and Gas Extraction Industry." Technical Resources Inc., Bethesda, MD. 1983, 45 pp.

[18] American Public Health Association. Standard Methods for the Examination of Water and Wastewater, 15th Ed. American Public Health Association. Washington, D.C. 1980. 1134 pp.

[19] Price, A.W., Macauley, J.M., and Clark, J.R. "Effects of Drilling Fluids on Thalassia testudinum and Its Epiphytic Algae," Report # U.S. Environmental Protection Agency, Environmental Research Laboratory, Gulf Breeze, FL, 1985, 23 pp.

[20] Winer, B.J. "Statistical Principles in Experimental Design." 2nd ED. McGraw HILL, New York, N.Y., 1971, 907 pp.

[21] Auble, G.T., Andrews, A.K., Ellison, R.A., Hamilton, D.B., Johnson, R.D., Roelle, J.E. and Marmurek, D.R. "Results of an Adaptive Environment Assessment Workshop Concerning Potential Impacts of Drilling Muds and Cuttings on the Marine Environment."

[22] Livingston, R.J., Diaz, R.J and White, D.C. "Field Validation of Laboratory-Derived Multispecies Aquatic Test Systems" EPA-600/X-85. Environmental Research Laboratory, Gulf Breeze, FL 1985. 56 pp.